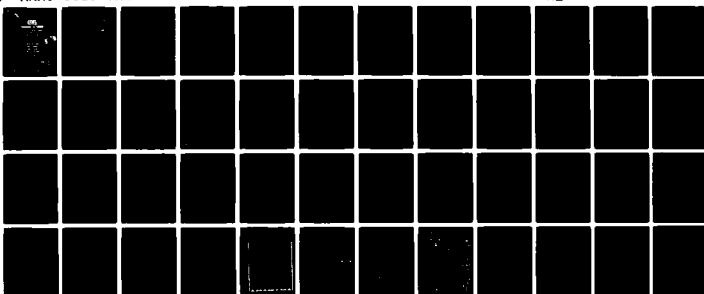


AD-A081 868

ADVANCED RESEARCH RESOURCES ORGANIZATION WASHINGTON DC F/6 5/9  
TRAINABILITY OF ABILITIES: TRAINING AND TRANSFER OF ABILITIES R--ETC(U)  
MAR 79 J M LEVINE, R E BRAHLEK, E J EISNER. N00014-77-C-0268  
ARRO-3010-TR2 NL

UNCLASSIFIED

1 11 1  
OL  
ALPHABET



END  
DATE  
FILMED  
4 80  
DTIC

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Trainability of Abilities: Training and Transfer of Abilities Related to Electronic Fault-Finding.		5. TYPE OF REPORT & PERIOD COVERED Technical Report 1 Jan 78 - 15 Mar 79
7. AUTHOR(s) Jerrold M. Levine, Rae E. Brahlek, Ellen J. Eisner, Edwin A. Fleishman		6. PERFORMING ORG. REPORT NUMBER ARRO-3818-TR2
9. PERFORMING ORGANIZATION NAME AND ADDRESS Advanced Research Resources Organization 4330 East West Highway, Suite 900 Washington, D. C. 20014		8. CONTRACT OR GRANT NUMBER(s) N00014-77-C-0268
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs Office of Naval Research (Code 458) Arlington, Virginia 22217		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N, RR042-06 RR042-06-01, NR 154-400
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) RR 042 06 RR 042 06 01		12. REPORT DATE Mar 79
		13. NUMBER OF PAGES 1259
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		15. SECURITY CLASS. (of this report)  Unclassified
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Training                      Electronic Fault-Finding Transfer of Training       Troubleshooting Abilities                     Ability Training		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and therefore reduce training time and increase personnel flexibility was investigated. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks but which had earlier (cont'd)		

Continued from Block 20--Abstract

been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The findings were discussed in relation to training regimens and the complexity of the criterion task.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DOC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

TRAINABILITY OF ABILITIES:  
TRAINING AND TRANSFER OF ABILITIES  
RELATED TO  
ELECTRONIC FAULT-FINDING

Jerrold M. Levine  
Rae E. Brahlek  
Ellen J. Eisner  
Edwin A. Fleishman

TECHNICAL REPORT

Prepared under Contract to the  
Personnel and Training Research Programs  
Psychological Sciences Division  
Office of Naval Research  
Department of the Navy

Contract No. N00014-77-C-0268  
NR No. 154-400

Approved for public release; distribution unlimited.  
Reproduction in whole or in part is permitted for  
any purpose of the United States Government.

ADVANCED RESEARCH RESOURCES ORGANIZATION

March 1979

# ABSTRACT

The feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and therefore reduce training time and increase personnel flexibility was investigated. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks but which had earlier been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The findings were discussed in relation to training regimens and the complexity of the criterion task.

Accession For	
NTIS GRA&I	
DDC TAB	
Unannounced	
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

## INTRODUCTION

The need for more flexible and adaptable Navy personnel is receiving increased recognition. While training and selection for specific job assignments continue, there is a need for programs which will produce personnel capable of performing a broader range of Navy tasks and jobs. A number of factors contribute to this trend, including the possibilities of fewer billets and smaller crew sizes, and the increased complexity of Navy jobs and tasks. Additionally, the impact of automation in man-machine systems has been to enhance the responsibility of the reduced number of personnel manning and maintaining these systems. Increased flexibility and adaptability of personnel in shifting to different tasks can minimize disruption in system effectiveness and minimize retraining costs associated with attrition and reassignment problems.

The purpose of the present research was to examine the feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and, therefore, reduce training time and increase personnel flexibility. If abilities can be improved through the use of diversified and intensive training, then this improvement should generalize to a variety of tasks and jobs in which the abilities are involved. Ability training may provide a more efficient approach for training individuals to perform a variety of different tasks than training for each specific task.

The identification of human abilities accounting for individual differences in cognitive, perceptual, and motor aspects of human performance has been the subject of extensive research (cf. Fleishman, 1964,

1972; French, Eckstrom, & Price, 1963; and Guilford, 1967). Considerable investigative effort has resulted in the conceptualization of abilities as broad capacities underlying performance in complex skills and related to performance in a variety of human tasks (Fleishman, 1967a, 1972). Typically, abilities are identified through correlational studies of human task performance, in which the fact of individual differences is exploited to gain insights about common processes required to perform different groups of tasks. Thus, abilities are defined by empirically determined relations among observed separate performances. Skills are more specific, and define levels of proficiency in particular tasks. These skills can be described in terms of component abilities required to perform them, with certain abilities shown to underly performance in many superficially different human tasks. There is much information now available as to which abilities are required for the performance of a variety of tasks.

Fleishman and his associates have shown that abilities are related to the progress individuals make in learning new, more complex skills, and to the final levels they attain after given amounts of training in these skills (Fleishman, 1967b, 1972; Fleishman & Hempel, 1965, 1956; and Fleishman & Fruchter, 1960). Similar investigations examined the relationships between abilities and learning rates and a variety of other learning measures (Fleishman & Ellison, 1969; Fruchter & Fleishman, 1967). From this research, it appears that abilities are more general than specific skills, and that abilities relate to progress in learning and training.

The idea that human abilities can be improved through training is a practical notion receiving little direct investigation. Most abilities

are considered to be the product of earlier learning and genetic factors (Ferguson, 1956; Gagne & Fleishman, 1959), and are defined as relatively stable attributes in the adult (Fleishman, 1972). However, there is some evidence that certain abilities can be enhanced by diversified training. Kysor and Hart (1969) found practice to improve number facility. Brinkman (1966) provided extensive training in the behaviors thought to be involved in spatial visualization (i.e., discrimination, recognition, organization, and orientation), and found significant improvement, on a spatial relations criterion test administered before and after training, for the trained group but not for an untrained control group. Stringer (1975) attempted to enhance spatial ability using various drawing training procedures and found that trained groups did better than an untrained control group on a test of spatial relations, but only when there was content similarity between the training and testing materials.

There is little doubt that performance on a task can be enhanced by training on similar tasks. Postman (1971) has reviewed the extensive literature on the direct relationship between task similarity and transfer of training. The major concern of the present study, however, is whether or not the training of an ability using a variety of tasks and materials, which are relatively dissimilar to a criterion task can enhance performance on the criterion task. In order to demonstrate such a phenomenon, it is necessary to select training materials and criterion tasks which tap the identical ability, but which are otherwise dissimilar. In this fashion, any improvement which might result from training could not be attributed to the similarity between training and criterion tasks. Instead, improvement could be inferred to have resulted from the enhancement of the ability



through training and the positive transfer of this training to the criterion task.

A recently completed comprehensive review of the literature (Hogan, 1978) relevant to training abilities revealed no other controlled test of whether or not ability training can ultimately transfer positively to dissimilar tasks requiring the same abilities. The early work at the beginning of this century was most directly related to this issue, but was fraught with methodological difficulties which precluded conclusions from being drawn (see Postman, 1971).

There is evidence, however, from other areas of research employing transfer paradigms which suggests that "nonspecific" transfer does, in fact, take place. Research on learning to learn has reported positive transfer when there was only minimal similarity between training and criterion tasks (Duncan, 1953, 1958; Posner & Keele, 1968). Additional support comes from simulation efforts which demonstrate that highly generalized training simulators promote transfer to very specialized tasks. Further, educational researchers have reported modest success at training intellectual abilities (see, for example, Parnes & Noller, 1972; and Maltzman & Morrisett, 1952).

The present study was designed to determine (a) whether intensive training could result in the improvement of an ability, and (b) whether such an improvement would transfer to a task which was dissimilar to the training tasks, but which required the same ability for successful performance.

## METHOD

The abilities selected for study were flexibility of closure and spatial scanning. Flexibility of closure is defined as the ability to identify or detect a known pattern (a figure, word, or object) which is hidden in background material. Spatial scanning is defined as speed in visually exploring a wide or complicated spatial field to detect or identify objects. The rationale for selecting these abilities was that (a) they did not involve highly learned or familiar types of behavior, (b) they could be represented by a wide variety of materials for training, and (c) they were dominant abilities in a laboratory task which simulated a Navy job. A diverse set of training materials was identified which had been shown to tap these abilities.

The criterion, or transfer task, was troubleshooting (electronic fault-finding). Previous research (Rose, Fingerman, Wheaton, Eisner, & Kramer, 1974) had indicated that flexibility of closure and spatial scanning were jointly the most important abilities in the task and that their importance increased with increasing problem difficulty. In that study twenty-one ability tests, hypothesized to contribute to performance on the troubleshooting task, were administered to a population of college students, who subsequently performed on the troubleshooting task. Flexibility of closure and spatial scanning together loaded approximately .30 on several measures of task performance. Other abilities related to performance included associative memory, syllogistic reasoning, and induction.

### Subjects

Sixty undergraduate students from local universities served as subjects. They were volunteers and were paid approximately \$3.00 per hour

for their participation. An additional performance-based monetary incentive was associated with all tasks which resulted in total earnings of from \$4.50 to \$5.00 per hour.

### Training Tasks

The training paradigm was designed to provide subjects with structured practice in utilizing the abilities of flexibility of closure and spatial scanning. It consisted of a series of nine self-administered, paper-and-pencil tasks with built-in feedback. Six tasks were designed to train flexibility of closure; three to train spatial scanning. The tasks were either derived from or patterned after standard ability and aptitude tests or were judged to substantially involve the ability of interest. The Mental Measurements Yearbook (O. Buros, Ed.) was used as a source for aptitude tests which were known to measure the abilities being studied. This source also provided factor loadings and correlational data for many of these tests which were used to substantiate that we were, in fact, training the abilities that we intended to train. The Kit of Factor-Referenced Cognitive Tests was also used as a source of training tasks.

In selecting and developing training tasks, certain guidelines were adhered to in addition to the obvious one that the tasks provide the trainee with structured practice in applying the abilities. These were:

- Task difficulty level had to be great enough to challenge subjects and to promote learning.
- The tasks had to be diverse so that subjects would be given the opportunity to apply the abilities in a variety of contexts. This would enable individuals to develop a repertoire of strategies appropriate to

various situations--an important condition for the transfer of general abilities.

- Training materials and tasks had to be as dissimilar as possible from the criterion task, while still requiring use of the same abilities. This requirement reduced the possibility of transfer occurring as a result of task similarity rather than ability training per se.

The training tasks selected for use are described below. The Appendix provides examples of items from each of these tasks.

- Task 1 -- "Hidden Figures" (flexibility of closure)  
Subjects were presented with a series of five geometric figures and a complex design in which one of the figures was embedded. The task was to visually search the design and identify which figure was contained within it, at the same time outlining the embedded figure.
- Task 2 -- "Copying" (flexibility of closure)  
In this task subjects copied a series of asymmetrical line drawings, composed of connecting line segments, onto grids formed of dots. Subjects' drawings had to be in the exact proportions and positions as the originals.
- Task 3 -- "Puzzles" (spatial scanning)  
Subjects were to solve line diagram puzzles by tracing over all the lines of the diagram with a continuous line (i.e., without tracing any line twice).

- Task 4 -- "Hidden Letters" (flexibility of closure)  
This task required subjects to search for capital letters outlined in dots and surrounded by random dot patterns.
- Task 5 -- "Inspection" (flexibility of closure)  
Subjects visually searched graphic designs for irregular lines, i.e., lines with breaks.
- Task 6 -- "Embedded Figures" (flexibility of closure)  
The task was to locate a particular figure which could be hidden within any of four patterns.
- Task 7 -- "Map Planning" (spatial scanning)  
The task was to identify the shortest route between two locations on a schematized map.
- Task 8 -- "Mazes" (spatial scanning)  
The task was to solve a series of mazes by tracing a path from the starting point to the goal.
- Task 9 -- "Altair Designs" (flexibility of closure)  
Subjects were presented with computer-generated graphics and were to locate specific designs hidden within the overall designs.

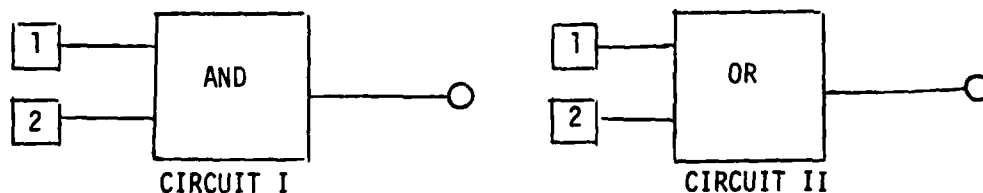
#### Ability Marker Tests

Two tests from the Kit of Factor-Referenced Cognitive Tests were used to assess subjects' ability levels. These were the "Hidden Patterns Test" for flexibility of closure, and "Choosing a Path" for spatial scanning. In the "Hidden Patterns Test," each item consisted of a geometrical pattern in which a single given configuration might or might not be embedded. The task was to mark each pattern in which the configuration occurs. In

the "Choosing a Path" test, each item consisted of a network of lines (as in an electrical circuit diagram) having many intersecting wires with five sets of terminals. The task was to trace the lines and to determine for which pair of terminals, marked S (start) and F (finish) there was a complete circuit. Both tests were speeded and scored in terms of number correct adjusted for guessing.

#### Troubleshooting Task

The troubleshooting task consisted of a series of problems in which subjects were required to locate malfunctions in diagrams of electrical circuits. The basic format was a digital-logic circuit in which the current flow at any point was determined by the preceding "AND" and "OR" logic gates. For example, in circuit 1 below, current can flow through the AND gate only if both switches 1 and 2 are depressed. In circuit 2,



only one switch is necessary to permit current through the OR gate. Each troubleshooting problem contained five such AND and OR gates.

Within each circuit diagram there was a single faulty wire or breakpoint which caused the current flow to be disrupted. The subject's task was to identify the location of that breakpoint by inserting a hypothetical probe (a "light bulb") at various locations (sockets) in the circuit and depressing the appropriate combination of switches to turn the light on.

If a particular light went on, then no break existed in that part of the circuit. On the other hand, if a light failed to go on, then one of the points lying on the path from the switch(es) to that light was faulty. A series of hypothetical probes (or tests) by the subject was required to isolate the actual breakpoint in each problem from the potential breakpoints.

Four basic circuit designs were used, each containing two AND gates and three OR gates in a different spatial configuration. For each basic circuit, three conditions of problem difficulty were created by varying the layout of the switches and wires while leaving the number and configuration of the logic gates unchanged. In the first level, the circuits appeared in an uncomplicated left-to-right, switch-to-gate-to-socket arrangement (Figure 1). In the second level, the basic overall left-to-right flow of current was maintained, but particular wires between switches and gates were interchanged so that proximal switches and gates were not necessarily connected, and wires sometimes intersected one another (Figure 2). In the third and most difficult level, locations of some of the switches were moved from the left side of the diagram, and the general left-to-right organization was disrupted (Figure 3). Manipulation of the problem difficulty variable resulted in twelve different problems (4 configurations x 3 levels of difficulty).

All problems were constructed with 5 AND/OR gates, 5 switches, and 16 possible breakpoints. Each of the problems so constructed was replicated once with a different breakpoint as the solution, thus resulting in a set of 24 problems.

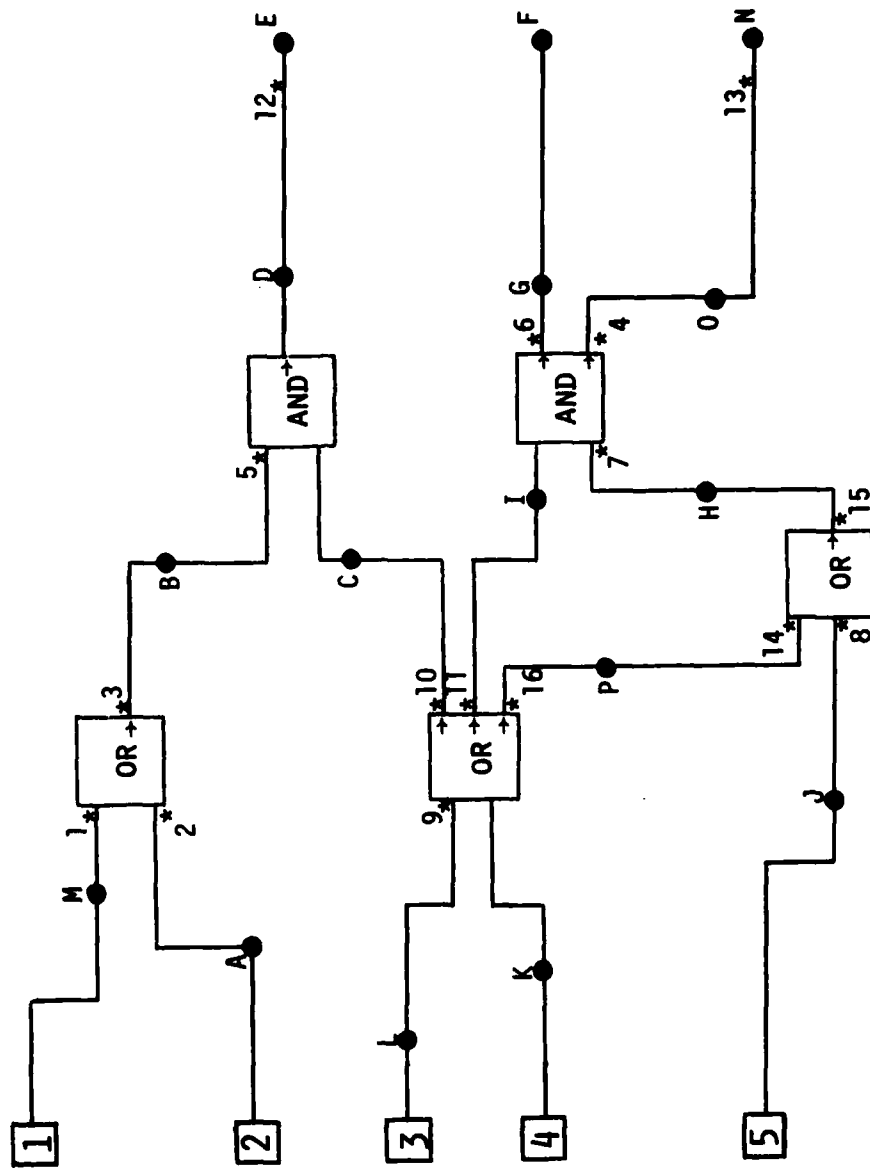


Figure 1. Example of troubleshooting problem at simplest level of problem difficulty. (Circles A-P represent light sockets--i.e., locations where subject can place probe. Numbered stars are potential breakpoints.)



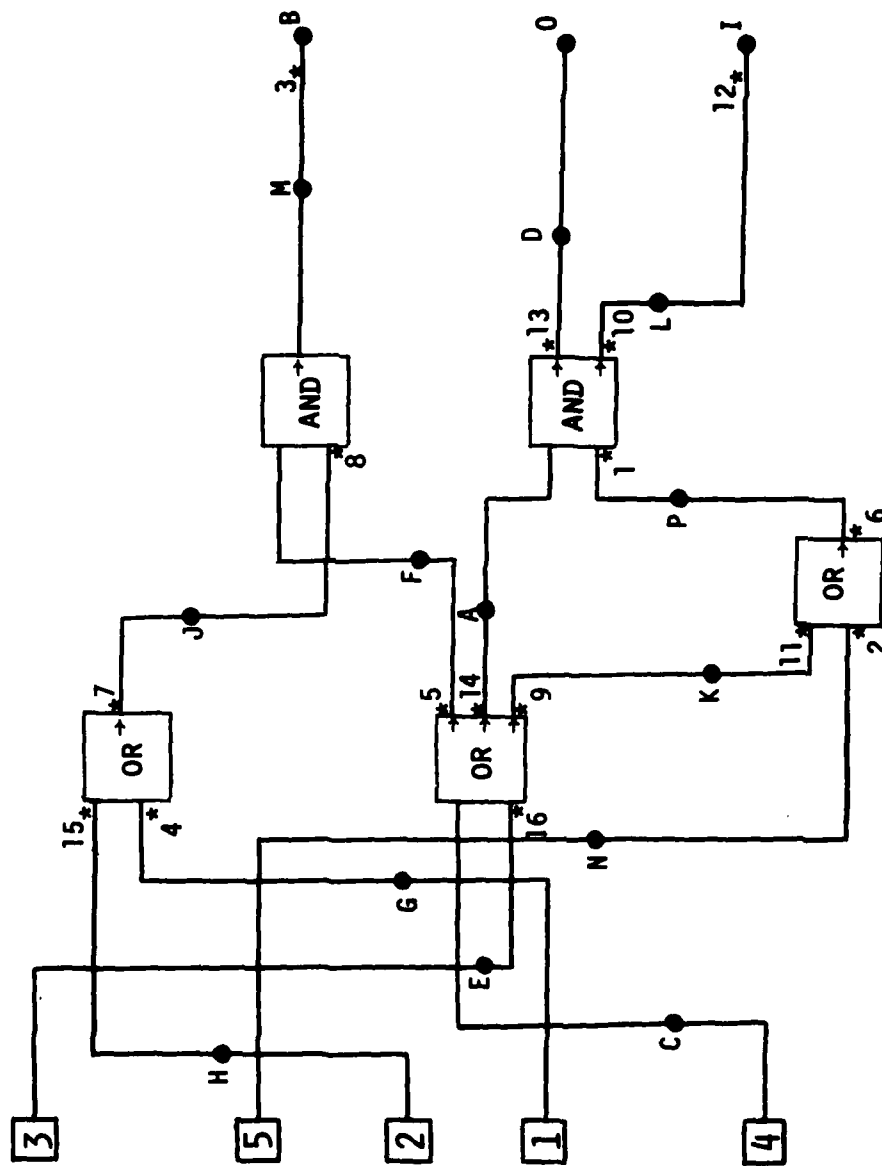


Figure 2. Example of troubleshooting problem at an intermediate level of problem difficulty.



### Experimental Design

Table 1 presents the experimental design of the study. There were five groups, each experiencing a different sequence of activities as described below. In Table 1, A is the criterion or transfer task (i.e., electronic troubleshooting), B is the set of materials selected to train the abilities of interest, and X is the designation for unrelated activity engaged in by a group of subjects in lieu of an experimental treatment.  $T_1$  represents the administration of the two ability marker tests prior to training.  $T_2$  represents the readministration of the tests subsequent to training.

Experimental groups ( $E_1$  and  $E_2$ ) received intensive ability training while control groups ( $C_1$  and  $C_2$ ) received no ability training. These four groups also performed on the criterion task. The design addressed two important questions: (1) Were the abilities trained? and (2) Did transfer occur?

The experimental groups differed only in that group  $E_1$  received a pretest on the criterion task. The use of a pretest, in which several similar, but not identical, problems from the criterion task are administered prior to any training, permits the collection of baseline measures of criterion task performance. Scores on this pretest can then be used to adjust scores on the posttest in order to eliminate any bias in the posttest scores which may be due to initial performance differences between experimental and control groups on the criterion task. A potential disadvantage of such pretesting, of course, is that the pretest itself may provide some training or practice that positively transfers to the posttest situation. In order to account for this, Group  $E_2$  was included.

TABLE 1  
Experimental Design

Group	Day 1 Pretest	Days 2-4 Train	Day 5 Posttest	n
E <sub>1</sub>	A	T <sub>1</sub> B T <sub>2</sub>	A	(15)
C <sub>1</sub>	A	X	A	(10)
E <sub>2</sub>	X	T <sub>1</sub> B T <sub>2</sub>	A	(15)
C <sub>2</sub>	X	X	A	(10)
C <sub>3</sub>		T <sub>1</sub> X T <sub>2</sub>		(10)

X = No Activity

A = Criterion Task

B = Training Tasks

T = Marker Tests of Abilities

Comparisons on the posttest between  $E_1$  and  $E_2$  reveal any effect due to practice on the criterion task during the pretesting phase.

Group  $C_1$  is a control group which did not receive any training. By comparing posttest performance for groups  $E_1$  and  $C_1$ , the question of transfer is addressed. Group  $C_2$  is a control group which received neither pretesting nor training. This group performed only on the criterion task. Performance on the posttest for the two control groups  $C_1$  and  $C_2$  can be compared to further assess the effect of practice during pretesting on the criterion task. Group  $C_3$  received only the ability marker tests.

The question of whether the abilities were trained is addressed by comparing performance on  $T_1$  and  $T_2$  for the two experimental groups. If performance on  $T_2$  is substantially greater than  $T_1$  in each of these groups, and if Group  $C_3$  does not demonstrate a significant improvement across administrations, then it can be concluded that success has been realized in training the abilities.

The need for ability marker tests requires some explanation. In most transfer research, the effect of training is assumed to be reflected in the posttest comparisons between experimental and control groups on the criterion task. In the present effort, it is possible for criterion task performance to be unaffected by training, despite having successfully trained the abilities under study. This is true because the criterion task requires (for successful performance) more than the two abilities under investigation--and the enhanced abilities may not contribute sufficiently to troubleshooting performance to result in improved proficiency. To identify whether or not transfer findings are specifically due (at least

in part) to the enhancement of the two abilities being investigated, marker tests which are "pure" measures of those abilities are required.

The ability marker tests also allowed for a partitioning of each of the experimental groups into high and low initial ability subjects. This permitted separate analyses of the results to be carried out in the event transfer of training was contingent upon the ability level subjects brought to the experimental situation.

#### Procedure

Subjects were randomly assigned to the five groups and participated in one experimental session daily for up to five consecutive days. In the first session (pretest) the troubleshooting task was administered; sessions two, three, and four consisted of ability training and administration of the ability marker tests preceding and following training; the final session (posttest) consisted of the administration of the troubleshooting task using a different and larger set of problems. Subjects were individually tested on the troubleshooting task, and received training and were administered the ability marker tests in groups of five.

On first reporting to the laboratory, subjects were briefed on the general nature of the study and the types of tasks they would be performing. They were informed that they could earn additional money in excess of the amount they were guaranteed for participating in the study, and that this amount was dependent upon the quality of their performance.

Subjects were next instructed in the concepts and mechanics of troubleshooting. This included presentation and discussion of six sample problems graded in difficulty. Subjects were told that each problem would have one

breakpoint and that their task was to discover this breakpoint. The instructions emphasized working as quickly as possible and solving for the breakpoint in the fewest possible tests. In order to encourage both speed and accuracy, a point system based on these two factors was devised. Subjects were told that they would earn 150 points for each problem correctly solved, and that 10 points would be subtracted for each test made, and five points for each minute elapsed until a problem was solved. No points would be awarded for an incorrect solution. They were informed that the total accumulated points would be converted to monetary payoff at the end of the experiment.

In order to reduce individual differences in strategy, subjects were told that efficient troubleshooters attempt to eliminate about half the remaining breakpoints from consideration with each test they make. Subjects were given a pad of paper and encouraged to use it in keeping track of tests performed and points eliminated, so that the memory factor in task performance would be minimized. These procedural steps were taken with the intent of reducing variance in performance due to the abilities of induction, syllogistic reasoning, and memory, identified in the earlier study (Rose et al., 1974).

Following the instructional session, subjects were administered the troubleshooting pretest. The pretest consisted of two practice problems plus six problems which had been randomly drawn from the twenty-four generated. Two problems of each of three difficulty levels were included. The order of presentation was randomized, with the limitation that no two problems with circuits having the same basic design could occur consecutively. Problem presentation order was the same for all subjects.

The subject made tests of the circuit by indicating the switch(es) he wanted to depress and the letter of the light he wished to probe. He was given immediate verbal feedback as to whether or not the light went on. The subject continued to formulate tests and receive feedback until he had determined the location of the breakpoint. Subjects were told whether or not they had correctly solved the problem and, if incorrect, were given the correct answer. Subjects were allowed an unlimited number of tests per problem and could make tests at their own pace. However, a time limit of 15 minutes per problem was set, so that if a solution was not arrived at within that time, the problem was terminated and scored as incorrect. Instructions and pretesting required approximately two hours.

The second, third, and fourth days consisted of the training phase of the experiment. Subjects participated in a single five-hour session on each of these days.

On the second day, the ability marker tests for flexibility of closure and spatial scanning were administered. Subjects were introduced to the training phase of the experiment and instructed that they would be performing a series of tasks over the next three days which would involve certain visual perceptual abilities. The abilities were described and examples of real-life activities requiring their use were given. Subjects earned incentive pay on the basis of how close they came to the maximum possible score on the training tasks.

Specific task instructions were read by the Experimenter and a sample problem was shown and explained prior to each training task. Tasks 1-4 were administered on the second day; tasks 5-9 on the third day. On the



fourth day, tasks 2, 3, 7, 8, and 9 were repeated. Tasks were self-administered; however, subjects were encouraged to ask questions about anything they didn't understand at any time during the task. Feedback was built into each training package and consisted of descriptions and/or diagrams of correct solutions which were displayed immediately following each page of problems. Subjects were instructed to complete a page of problems, then to compare their work with the correct solutions before continuing with the task. The single exception to this procedure was task 7, a search task, wherein feedback was received after the entire task was completed.

Subjects worked at their own pace through each task. Because training occurred in a group situation, subjects were required to wait until everyone in the group had completed the previous task before proceeding to the next one. Tasks varied in terms of average completion time from ten minutes to one and one-half hours. The tasks were self-scored, enabling subjects to determine how well they did in comparison with the maximum possible score. Subjects were carefully monitored to insure accurate scoring. At the end of the last training session, both ability marker tests were readministered.

On day 5 (the final session), subjects returned for the troubleshooting posttest. Instructions were repeated in a slightly abbreviated form, followed by the two practice problems used in the pretest. Each subject was then individually administered eighteen posttest problems, representing six problems at each level of difficulty. As in the pretest, the order of presentation was randomized and was identical for all subjects. The

posttest session lasted approximately four hours. At the end of the session, the amount of incentive pay earned by the subject for all tasks was computed and added to the fee guaranteed for participating in the experiment. Subjects were paid and questions about the nature and purpose of the study were answered at that time.

The preceding described the treatment of subjects assigned to Group  $E_1$ . Subjects assigned to Group  $E_2$  were treated in an identical fashion to Group  $E_1$ , except that the first day's session (pretest) was omitted. Subjects in Group  $C_1$  received both the pretest and posttest, but did not receive ability training. Subjects in Group  $C_2$  received only the posttest and those in Group  $C_3$  received only the ability market tests. A total of sixty subjects were tested according to the design in Table 1.

## RESULTS

Analyses were carried out on the scores obtained from the ability marker tests and the troubleshooting task. Performance measures for the troubleshooting task included accuracy, number of tests to solution, number of erroneous tests (those for which there was no pathway connecting the switch and light, or in which current could not flow through the AND/OR gates), and time to solution for each problem.

Mean scores on both administrations of the ability marker tests were contrasted for the groups receiving training ( $E_1$  and  $E_2$ ) and the untrained control group ( $C_3$ ) in order to determine whether the training regimen resulted in improvement of the abilities being trained. The results indicated that spatial scanning was successfully trained, but that flexibility of closure was not. Figure 4 shows the mean scores for the several groups who were given the ability tests. On the spatial scanning test, the two trained groups showed a significant improvement between administrations ( $t(28) = 4.43$  and  $2.34$ ,  $p < .01$ , for Groups  $E_1$  and  $E_2$ , respectively), while the untrained group showed no statistically significant improvement. On the flexibility of closure test, however, both trained and untrained groups showed significant improvement across the two administrations of the ability test ( $t(28) = 3.71$ ,  $t(26) = 5.28$ , and  $t(17) = 3.71$ ,  $p < .01$ , for Groups  $E_1$ ,  $E_2$ , and  $C_3$ , respectively). Since the untrained control group showed significant improvement between test administrations, we cannot conclude that the improvement in the experimental groups was due to training.

A one between-subject, two within-subject analysis of variance was carried out on the data obtained from the troubleshooting posttest. The

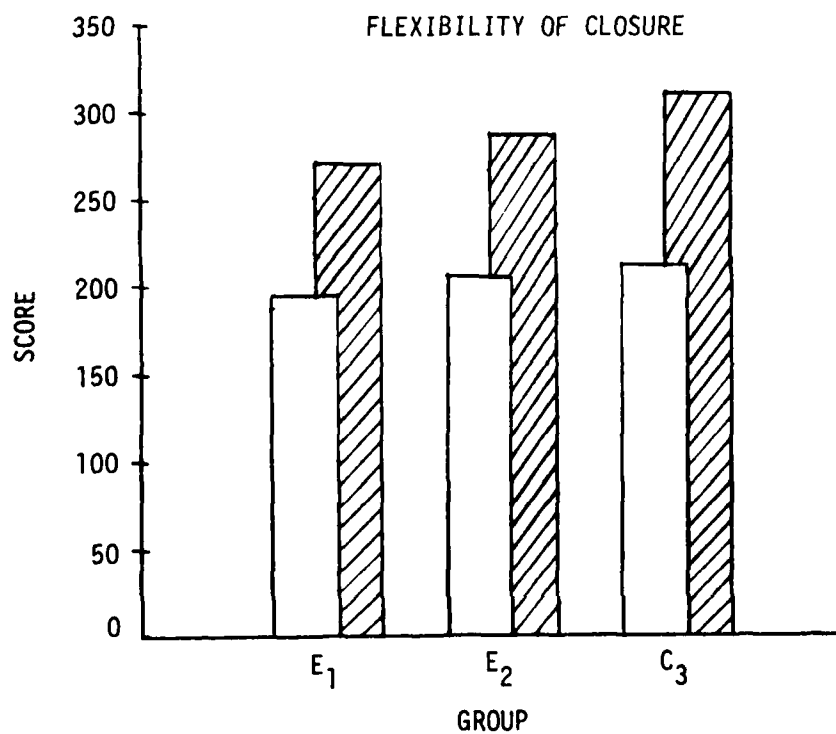
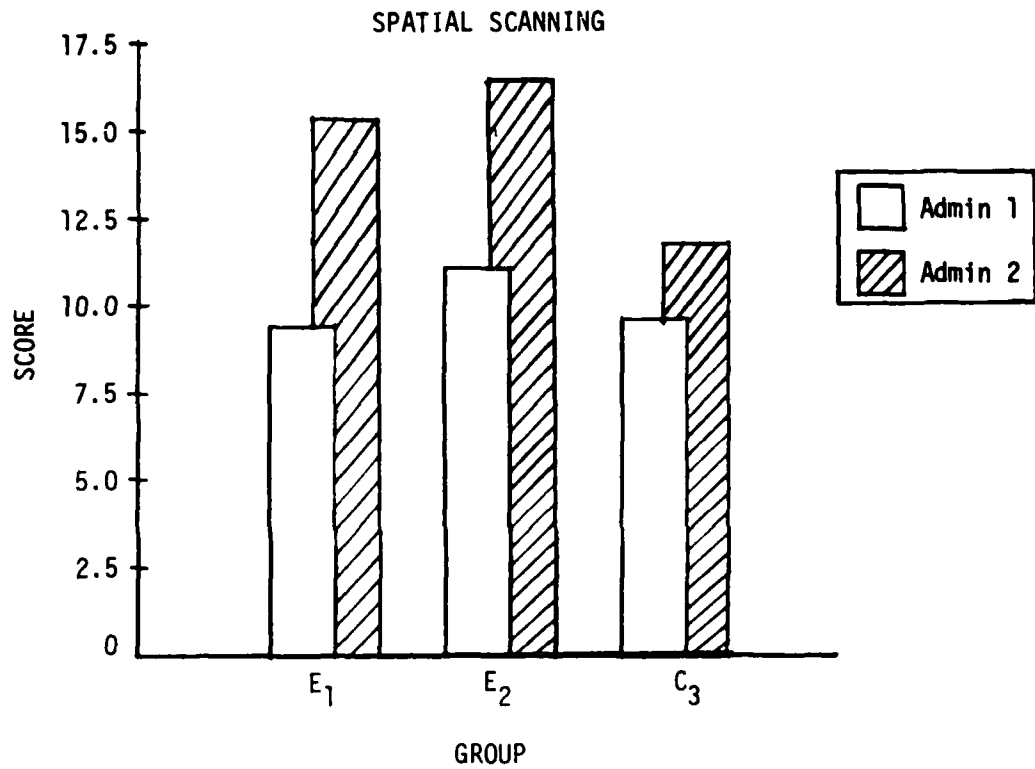


Figure 4. Mean scores on ability marker tests.

between-subject variable was groups. The within-subject variables were blocks of trials and problem difficulty. There were four groups and three blocks of six problems, each block containing problems of three levels of difficulty. Analyses were carried out for each of the four measures of performance defined earlier.

Of principal importance were the main effect of groups and the group  $\times$  trial blocks and group  $\times$  problem difficulty interaction effects. Although we were clearly concerned with differences among the trained and untrained groups, we were equally interested in whether the influence of training varied as a function of practice on and difficulty of the task.

The results indicated that the only effects of interest which were statistically reliable were for the time to solution performance measures. Here, the main effect of groups and the groups  $\times$  problem difficulty interaction were significant ( $F(3, 46) = 5.19$  and  $F(6, 92) = 3.30$ ,  $p < .01$ , respectively). The significant main effect of groups was evaluated using  $t$ -tests to make comparisons among the means. The results indicated that there were no differences between the trained ( $E_1$  and  $E_2$ ) and untrained ( $C_1$  and  $C_2$ ) groups, but that time to solution was significantly less for pretested groups ( $E_1$  and  $C_1$ ) than for groups not given a troubleshooting pretest ( $E_2$  and  $C_2$ ). Thus, while training had no impact upon performance on the troubleshooting task, prior practice on a pretest improved subsequent posttest time to solution. Table 2 presents the group means for each of the dependent variables.

The group  $\times$  problem difficulty interaction is depicted in Figure 5. Contrasts among means indicated that  $E_1$  solved problems more quickly than

TABLE 2  
Troubleshooting Group Means

Performance Measure	Group				Grand Mean
	E <sub>1</sub>	C <sub>1</sub>	E <sub>2</sub>	C <sub>2</sub>	
Accuracy	.88	.88	.90	.89	.89
No. of Tests	5.13	5.17	4.85	5.55	5.14
No. Erroneous Tests	.22	.24	.22	.24	.23
Time to Solution	177.68	179.71	242.04	267.43	215.35

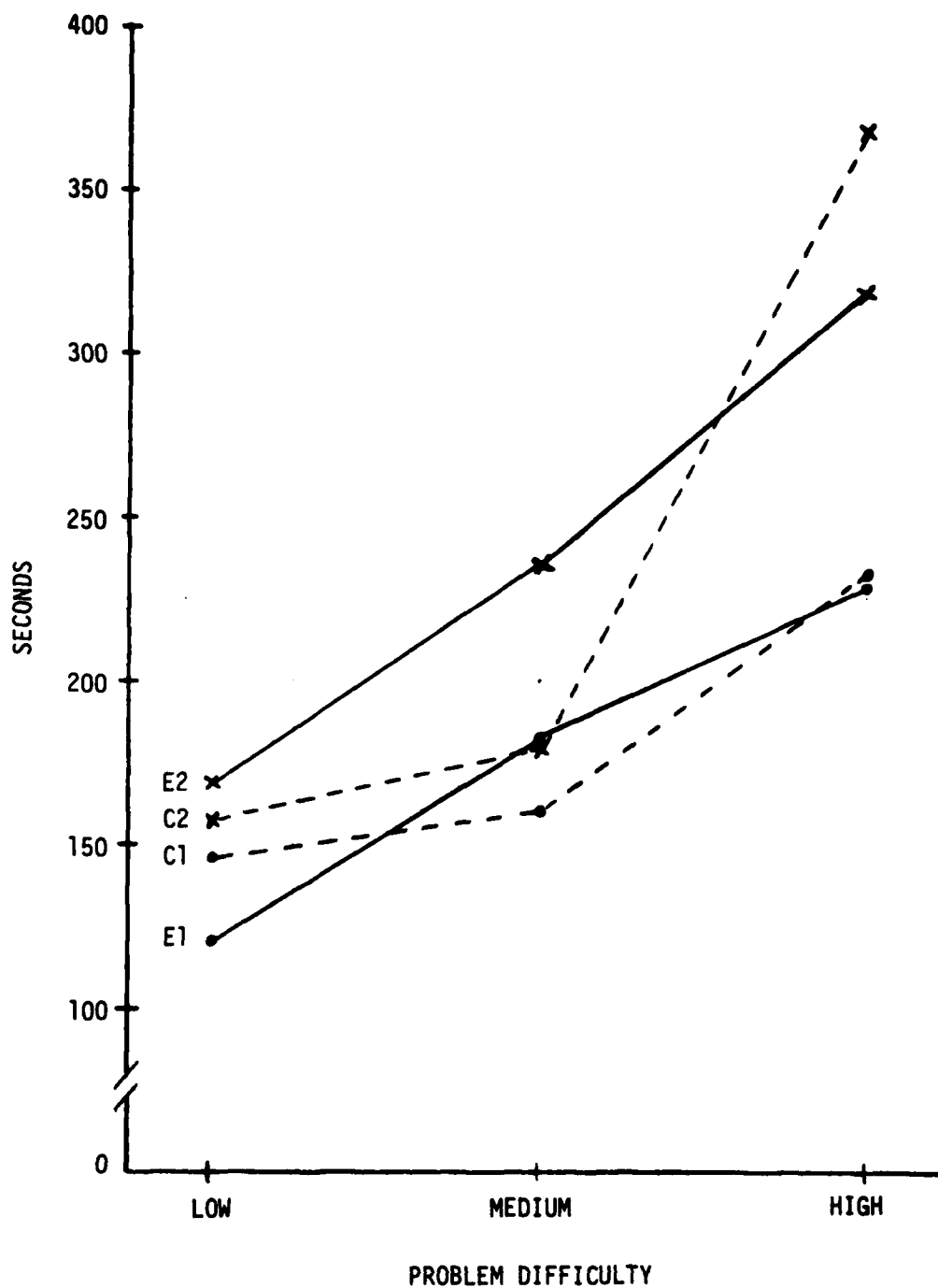


Figure 5. Mean time to problem solution as a function of group and problem difficulty.

$E_2$  under all levels of problem difficulty and that  $C_1$  was better than  $C_2$  only for the most difficult set of problems.

Although there was little technical interest in other findings from the analyses of variance, it should be noted that the main effects of trial block were significant for each performance measure. Essentially, performance on the last two blocks of problems was nearly identical and was significantly superior to performance on the first trial block. The main effect of problem difficulty was also significant for all performance measures except number of tests. Performance was consistently poorer as problem difficulty increased.

Although contrasts among trained and untrained groups on posttest performance ( $E_1$  vs.  $C_1$  and  $E_2$  vs.  $C_2$ ) failed to demonstrate any significant effect of training, it was premature to conclude that training did not impact upon posttest performance. The lack of a training effect could have been due to initial differences among groups in their skill at solving troubleshooting problems despite the random assignment of subjects to groups. A more sensitive test of the transfer effect, therefore, was carried out on the data from Groups  $E_1$  and  $C_1$  using analyses of covariance. The analyses of covariance had the effect of adjusting posttest scores for individual differences on the pretest (i.e., essentially matching the groups on the basis of the pretest). The covariate was the mean pretest score for each subject on each of the four dependent variables.

The analyses of covariance failed to reveal any significant effects of interest. Groups  $E_1$  and  $C_1$  (both pretested, but only the former trained)



did not differ on any measure. This result was consistent with the outcome of the analyses of variance. There were no significant group x trial block or group x problem difficulty interactions. Overall, transfer (computed as  $E-C/C$ ) ranged from -3.4% to 14.3% across the four measures of troubleshooting performance. Figure 6 shows the mean scores for the two pretested groups on each block of problems for each of the dependent variables evaluated. Averaged over all subjects in the two groups, adjusted mean accuracy was 87%; the number of tests to solution was 5.15; the number of erroneous tests made was .22; and time to problem solution was 177 seconds.

On the assumption that ability training may be effective only for individuals who bring a relatively low level of the ability to the task, additional analyses were carried out. Subjects in Group  $E_1$  were partitioned into the five highest and five lowest scorers on the first administration of the spatial scanning test. A similar separate partitioning based upon the flexibility of closure test was also carried out. Performance of each subgroup was compared to that of the untrained control group. Analyses of covariance were used on this reduced sample with mean pretest scores as the covariate. These analyses were carried out only on the number of tests and time to solution measures, since earlier analyses showed there was little variability among subjects in terms of accuracy and number of erroneous tests.

The results indicated no differences between either the high ability or low ability subgroups of trained subjects and the untrained control group for the spatial scanning or flexibility of closure breakdowns.

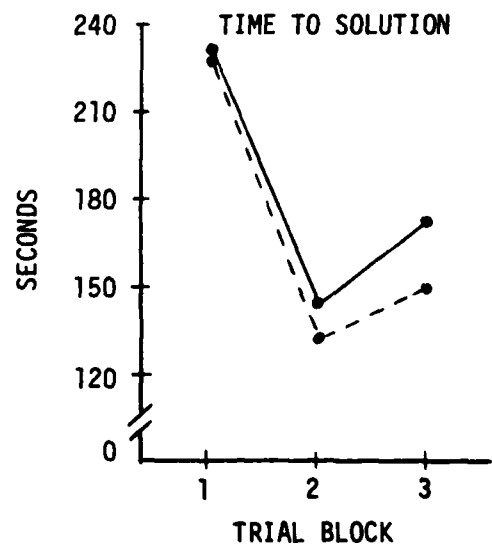
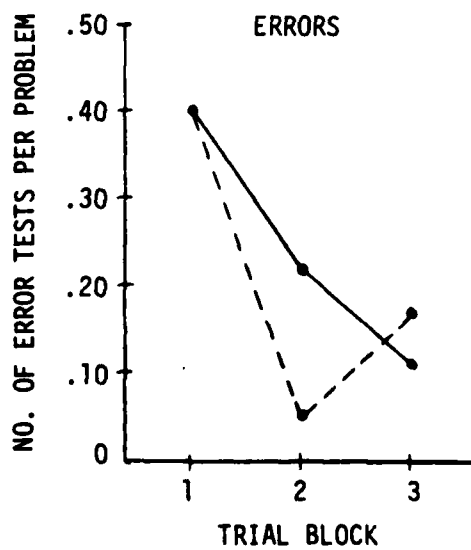
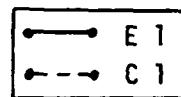
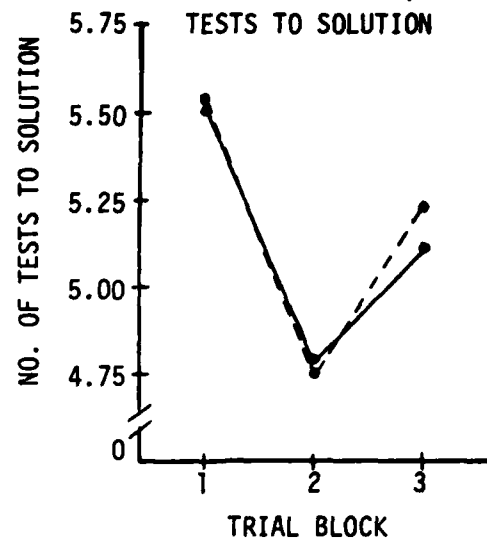
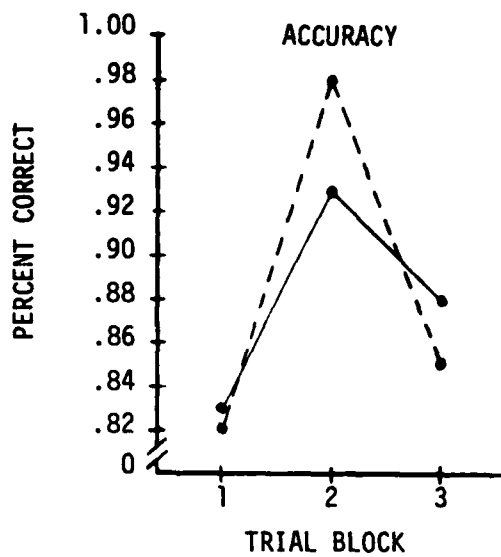


Figure 6. Adjusted mean performance of trained groups and untrained groups as a function of trial blocks.

No evidence of transfer of training was revealed on either high or low ability groups. The only significant result was that subjects classified as low on spatial scanning required more time to solution than subjects classified as high.

## DISCUSSION

Extensive training of two abilities involved in an electronic fault-finding task (troubleshooting) resulted in significant enhancement of spatial scanning but not of flexibility of closure as measured by standard ability tests administered before and after training. There was no evidence that performance on the troubleshooting task was improved significantly as a result of training (i.e., there was no transfer of training).

The measures of training effectiveness were the "Hidden Patterns Test" for flexibility of closure and "Choosing a Path" for spatial scanning. These tests, taken from the Kit of Factor-Referenced Cognitive Tests, are generally accepted as valid measures of the abilities under study. There were marked improvements in scores between administrations of the flexibility of closure marker test for the untrained control group ( $C_3$ ) as well as for the trained groups ( $E_1$  and  $E_2$ ). The improvement in group  $C_3$  may have been due to the ease and highly speeded nature of the test. The combination of simplicity (there were rarely any incorrect answers) and speed could have resulted in improvement across administrations owing simply to a learning to learn phenomenon. Thus, it is possible that training of flexibility of closure was effective but that it went undetected because the test instrument used was not sufficiently complex to be sensitive to improvement.

The training regimen adopted in this study was based upon extensive self-paced practice with feedback using a broad array of tasks having a wide range of difficulty and known to require either flexibility of closure or spatial scanning. Fourteen hours of training were given over a three-day period. Clearly, there were other possible training approaches which

might have had an impact on criterion task performance. For example, training could have been made even more extensive and distributed over a longer period of time in order to increase its potential effectiveness. For practical reasons this could not be carried out in the present study; the logistics of having our subjects return for additional sessions over more days or weeks could not be accommodated in a cost effective fashion. A captive population would be required to engineer such an extended training paradigm. The amount of training required to improve an ability is a research issue which has not been addressed in previous research and could not be in the present study. Consequently, the choice of time parameters in the training procedure was somewhat arbitrary, guided largely by practical constraints.

In addition to a variety of modifications in the phasing and amount of training provided by our approach, there are other approaches which could have been adopted. We could have identified and then trained the strategies which result in successful performance on tasks having similar ability requirements. Alternately, we could have obtained data on specific behaviors involved in the criterion task (which were relevant to the two abilities of interest) and developed a training paradigm around those behaviors. We know of no basis for choosing among these varied approaches or other possible training paradigms; and it was beyond the scope of this effort to evaluate the alternatives empirically.

A careful examination of the relationship between the abilities required for successful performance on the criterion task and the abilities which were trained may offer some explanation for the failure to find significant positive transfer of training. It will be recalled that

Rose et al. (1974) found that spatial scanning and flexibility of closure together were the dominant abilities in a troubleshooting task identical to the one used in the present study. However, the separate contribution of each of these two abilities to troubleshooting performance could not be isolated. It should also be recalled that there were other abilities involved in this task, including memory, induction, and reasoning. While flexibility of closure and spatial scanning jointly had the highest factor loading of any other ability on several indices of troubleshooting performance, the other abilities combined accounted for 70% of the variance in performance. Therefore, failure to obtain transfer of training may reflect the fact that flexibility of closure and spatial scanning did not account for a sufficient proportion of the ability requirements of the task. Despite the fact that one of those abilities (spatial scanning) was enhanced through training, this enhancement did not substantially contribute to the quality of subsequent troubleshooting performance. It is important to note that speculations concerning the reasons transfer of training did not occur must include the possibility that ability enhancement simply does not transfer to dissimilar tasks requiring the same abilities.

In order to assess the degree to which the troubleshooting task related to the abilities trained in the present study, correlation coefficients were computed between the scores on the first administration of the ability marker test and mean troubleshooting scores on the posttest for all trained subjects. Number of points earned was used as the measure of troubleshooting performance, since this index was based upon both speed and accuracy. The average correlations were .26 and .51 for flexibility

of closure and spatial scanning, respectively; the latter correlation was significantly different from zero.

The results of the present study were not conclusive. A follow-up study is planned which will attempt to train a single ability (spatial visualization) and evaluate transfer on three different criterion tasks which involve this ability to varying degrees. For one of these criterion tasks, visualization is the only required ability. Consequently, a more precise evaluation of the issue of transfer of ability training will be possible.

## REFERENCES

- Brinkmann, E. H. Programmed instruction as a technique for improving spatial visualization. Journal of Applied Psychology, 1966, 50(2), 179-184.
- Buros, Oscar, K. (Ed.) Mental Measurements Yearbook (8th edition). Highland Park, N.J.: Gryphon, 1979.
- Duncan, C. P. Transfer after training with single versus multiple tasks. Journal of Experimental Psychology, 1958, 55, 63-72.
- Duncan, C. P. Transfer in motor learning as a function of degree of first-task learning and inter-task similarity. Journal of Experimental Psychology, 1953, 45, 1-11.
- Educational Testing Service. Kit of Factor-Referenced Cognitive Tests. Princeton, N.J., 1976.
- Ferguson, G. A. On transfer and the abilities of man. Canadian Journal of Psychology, 1956, 10, 121-131.
- Fleishman, E. A. On the relation between abilities, learning, and human performance. American Psychologist, 1972, 27, 1017-1032.
- Fleishman, E. A. Individual differences and motor learning. In R. M. Gagne (Ed.), Learning and individual differences. Columbus, Ohio: Charles E. Merrill, 1967. (a)
- Fleishman, E. A. Performance assessment based on an empirically derived task taxonomy. Human Factors, 1967, 9, 349-366. (b)
- Fleishman, E. A. The structure and measurement of physical fitness. Englewood Cliffs, N.J.: Prentice Hall, 1964.
- Fleishman, E. A., & Ellison, G. D. Prediction of transfer and other learning phenomena from ability and personality measures. Journal of Educational Psychology, 1969, 60, 300-314.
- Fleishman, E. A., & Fruchter, B. Factor structure and predictability of successive stages of learning Morse code. Journal of Applied Psychology, 1960, 44, 96-101.
- Fleishman, E. A., & Hempel, W. E., Jr. Factorial analysis of complex psychomotor performance and related skills. Journal of Applied Psychology, 1956, 40, 96-104.
- Fleishman, E. A., & Hempel, W. E., Jr. Changes in factor structure of a complex psychomotor test as a function of practice. Psychometrika, 1954, 18, 239-252.



- French, J. W., Eckstrom, R. B., & Price, L. A. Manual for kit of reference tests for cognitive factors. Princeton, N.J.: Educational Testing Service, June 1963.
- Fruchter, B., & Fleishman, E. A. A simplicial design for the analysis of correlational learning data. Multivariate Behavior Research, 1967, 2, 83-88.
- Gagne, R. M., & Fleishman, E. A. Psychology and human performance: An introduction to psychology. New York: Henry Holt, 1959.
- Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.
- Hogan, J. C. Trainability of abilities: A review of non-specific transfer issues relevant to ability training. (ARRO Technical Report R78-1). Washington, D. C.: Advanced Research Resources Organization, January 1978.
- Kysor, P., & Hart, J. Practice effect on number facility performance. Psychological Reports, 1969, 24(1), 43-48.
- Maltzman, I., & Morrisett, L., Jr. Different strengths of set in the solution of anagrams. Journal of Experimental Psychology, 1952, 44, 242-246.
- Parnes, S. J., & Noller, R. B. Applied creativity: The creative studies project: II. Results of the two-year program. Journal of Creative Behavior, 1972, 6, 164-186.
- Posner, M. I., & Keele, S. W. On the genesis of abstract ideas. Journal of Experimental Psychology, 1968, 77, 353-363.
- Postman, L. Transfer, interference, and forgetting. In J. W. King and L. A. Riggs (Eds.), Woodward and Schlosberg's experimental psychology. New York: Holt, Rinehart, & Winston, 1971, 1019-1132.
- Rose, A. M., Fingerman, P. W., Wheaton, G. R., Eisner, E., & Kramer, G. Methods for predicting job-ability requirements: II. Ability requirements as a function of changes in the characteristics of an electronic fault-finding task. Washington, D. C.: American Institutes for Research, Technical Report R74-6, August 1974.
- Stringer, P. Drawing training and spatial ability. Ergonomics, 1975, 18(1), 101-108.

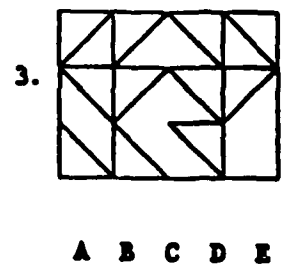
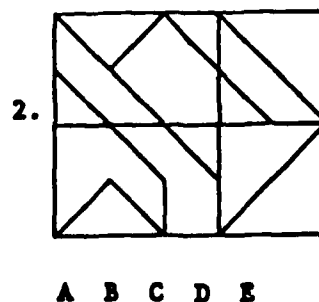
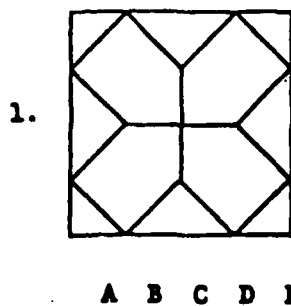
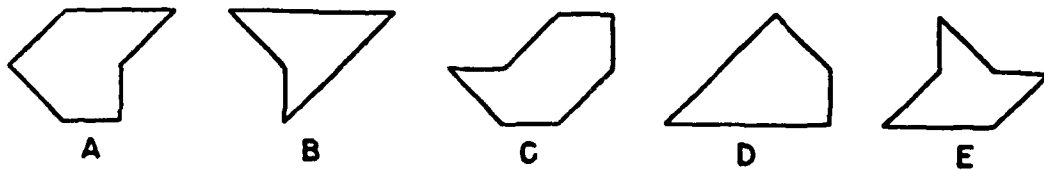
APPENDIX  
EXAMPLES OF TRAINING TASKS

TASK 1 -- Hidden Figures (F.C.)

Find one of the figures A-E in each of the designs.

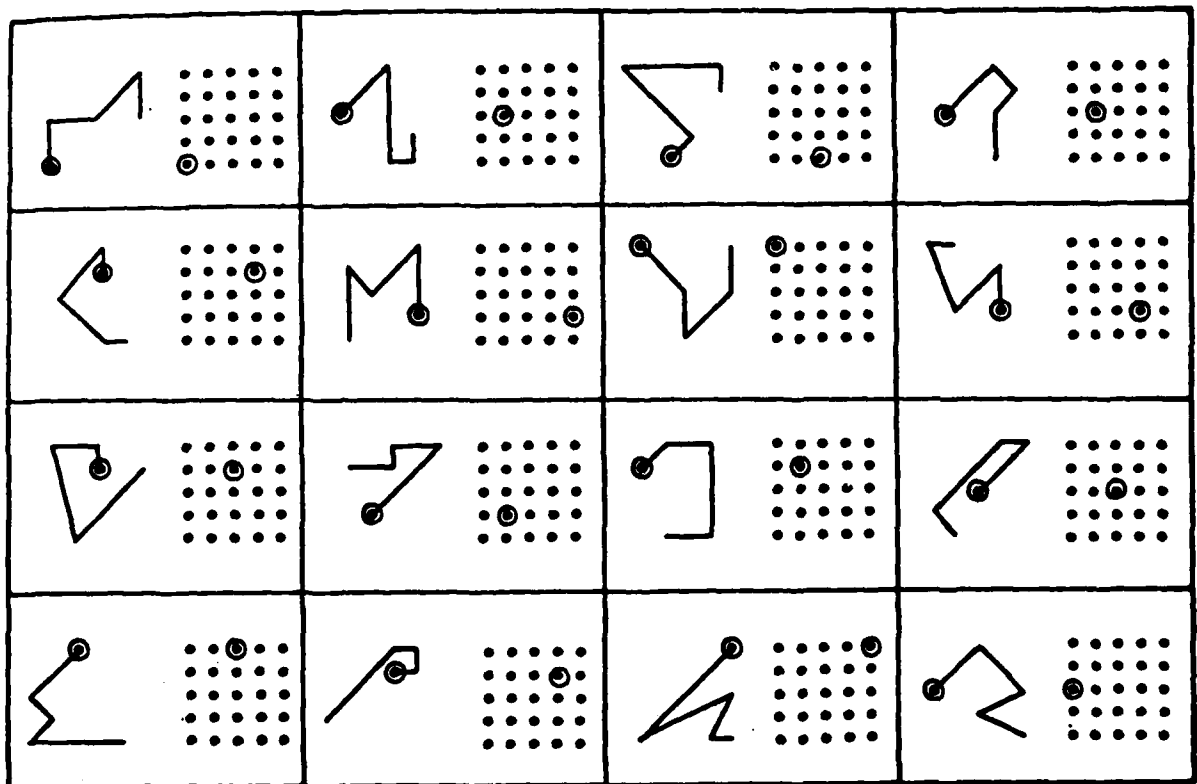
Circle the appropriate letter beneath the design; then outline the figure within the design.

Figures are always right side up and the same size as shown above the designs. There is one and only one figure in each design.



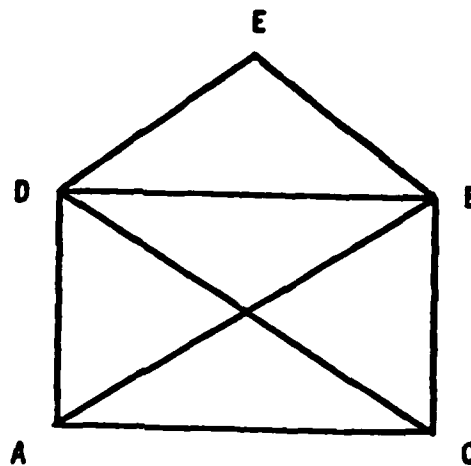
# TASK 2 -- Copying (F.C.)

Copy each pattern in the dotted space to the right of it. Begin at the circled dot. You may erase.



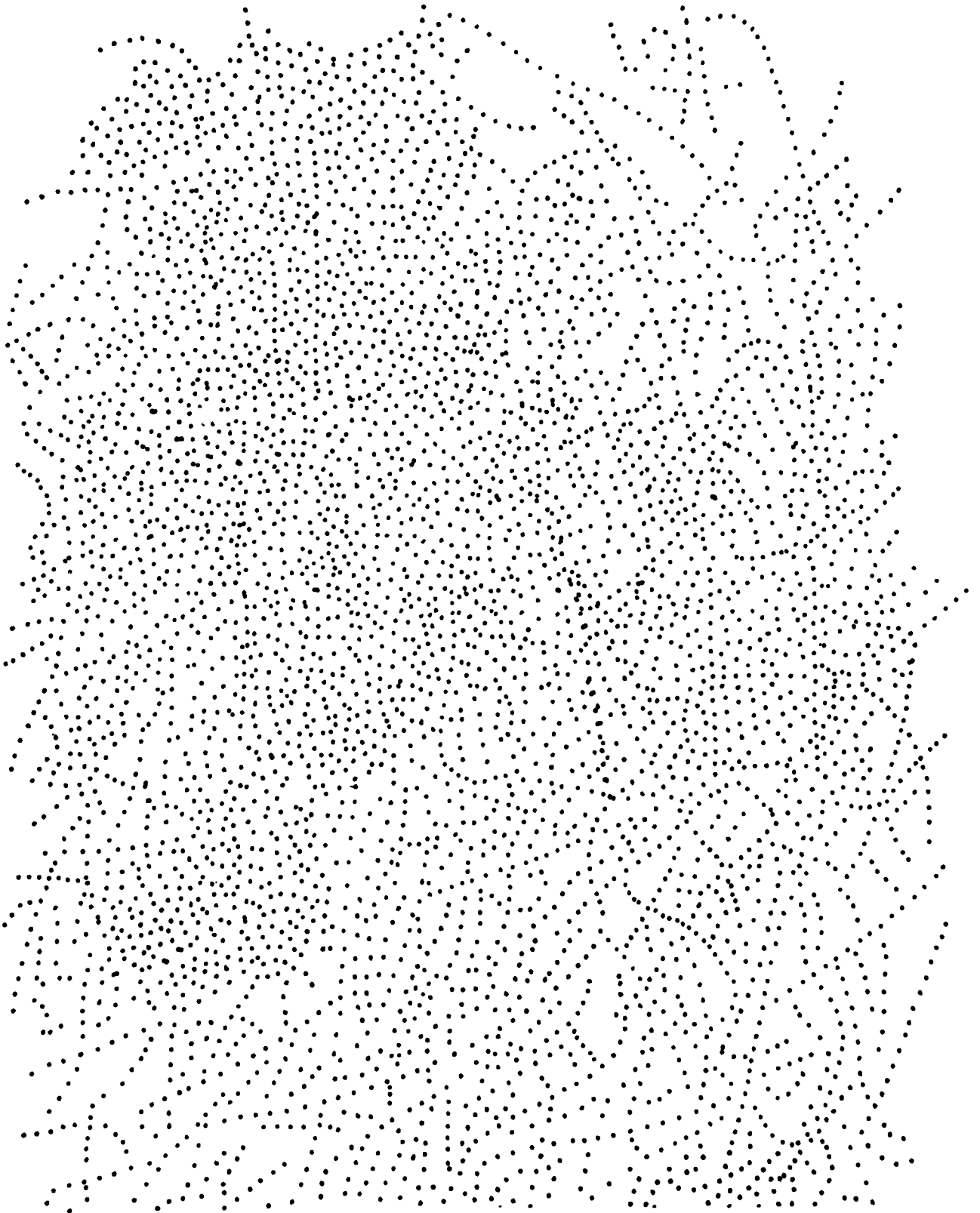
TASK 3 -- Puzzles (S.S.)

Trace over all the lines of the diagram without tracing any line twice and without repositioning your pencil on the diagram.



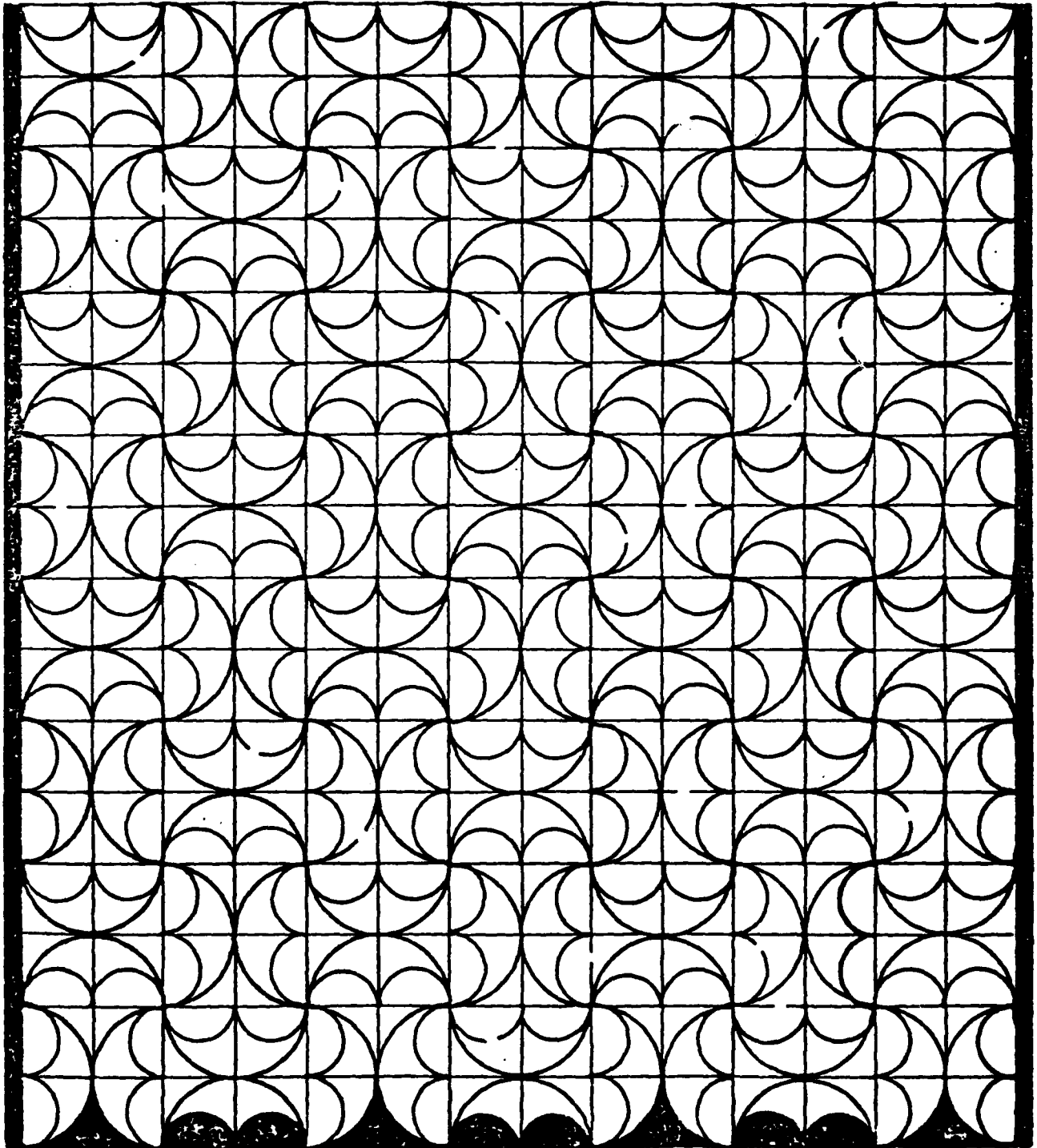
TASK 4 -- Hidden Letters (F.C.)

Find the letter "H" in the dot pattern below.



TASK 5 -- Inspection (F.C.)

Locate and circle as many breaks in the lines as you can find.


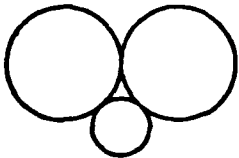
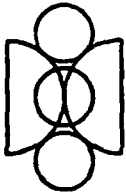


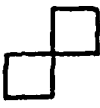
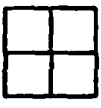
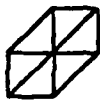
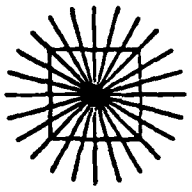

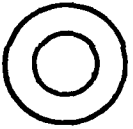
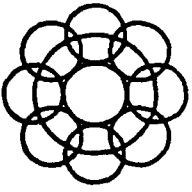

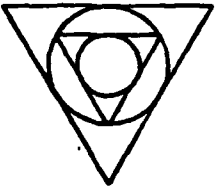



# TASK 6 -- Embedded Figures (F.C.)

Put a "/" under each design in which the figure on the left is hidden. Then darken the outline of the figure in the design.

The figure may appear in any, all, or none of the 4 designs.

The figure is always right side up and the same size in the designs.

1.					
		( )	( )	( )	( )
2.					
		( )	( )	( )	( )
3.					
		( )	( )	( )	( )



# TASK 7 -- Map Planning (S.S.)

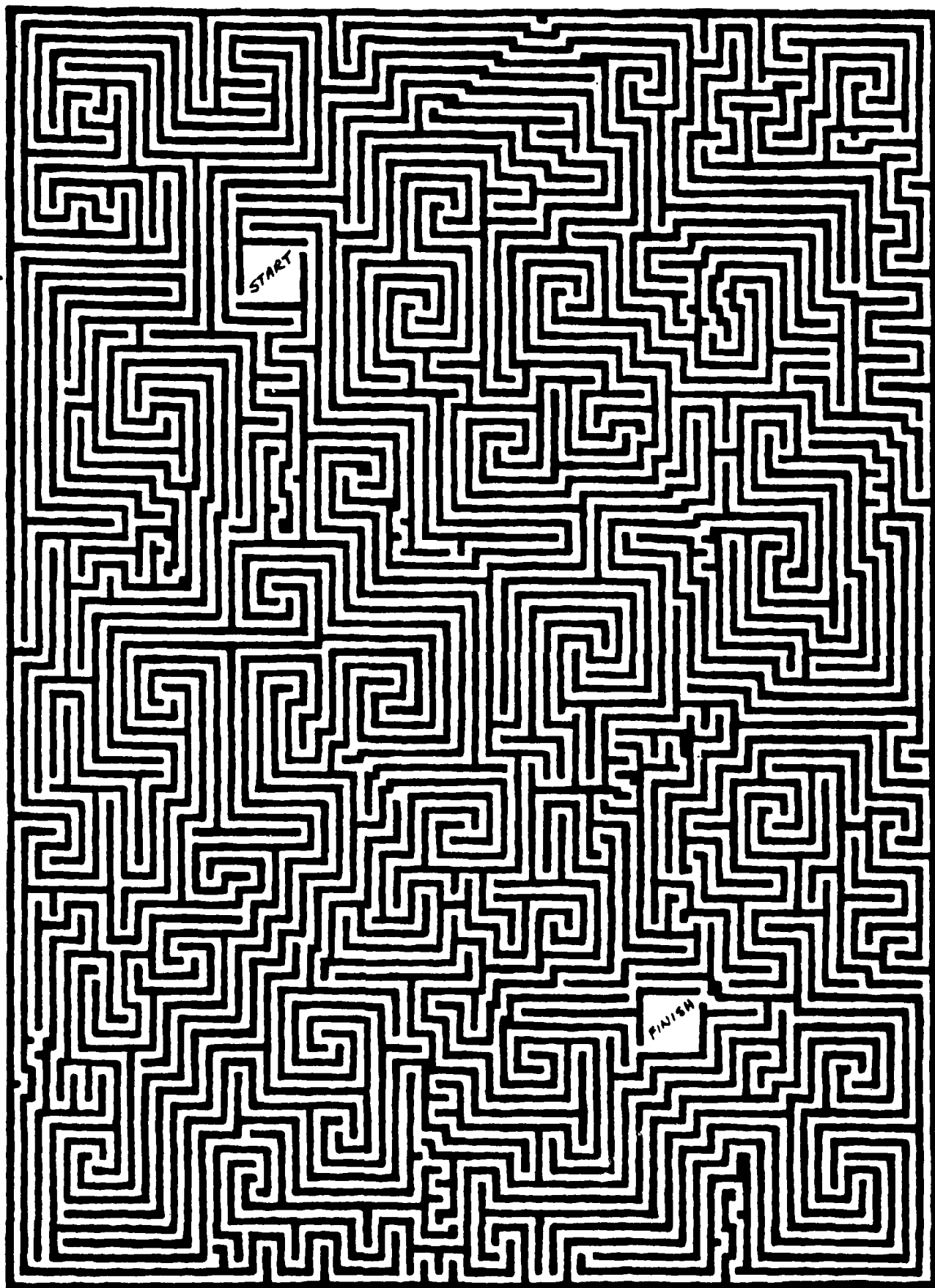
Find the shortest route between the points listed at the right side of the map. You can not pass where there are circles. The numbered squares are buildings. The number of the building passed is your answer.

The shortest route will always pass along the side of one and only one of the numbered buildings.

A building is not considered as having been passed if a route passes only a corner and not a side.

								<p>The shortest route from:</p>	<p>Passes building:</p>
1. A to Z	_____								
2. E to S	_____								
3. P to J	_____								
4. V to K	_____								
5. O to F	_____								
6. G to M	_____								
7. D to Q	_____								
8. F to T	_____								

TASK 8 -- Mazes (S.S.)

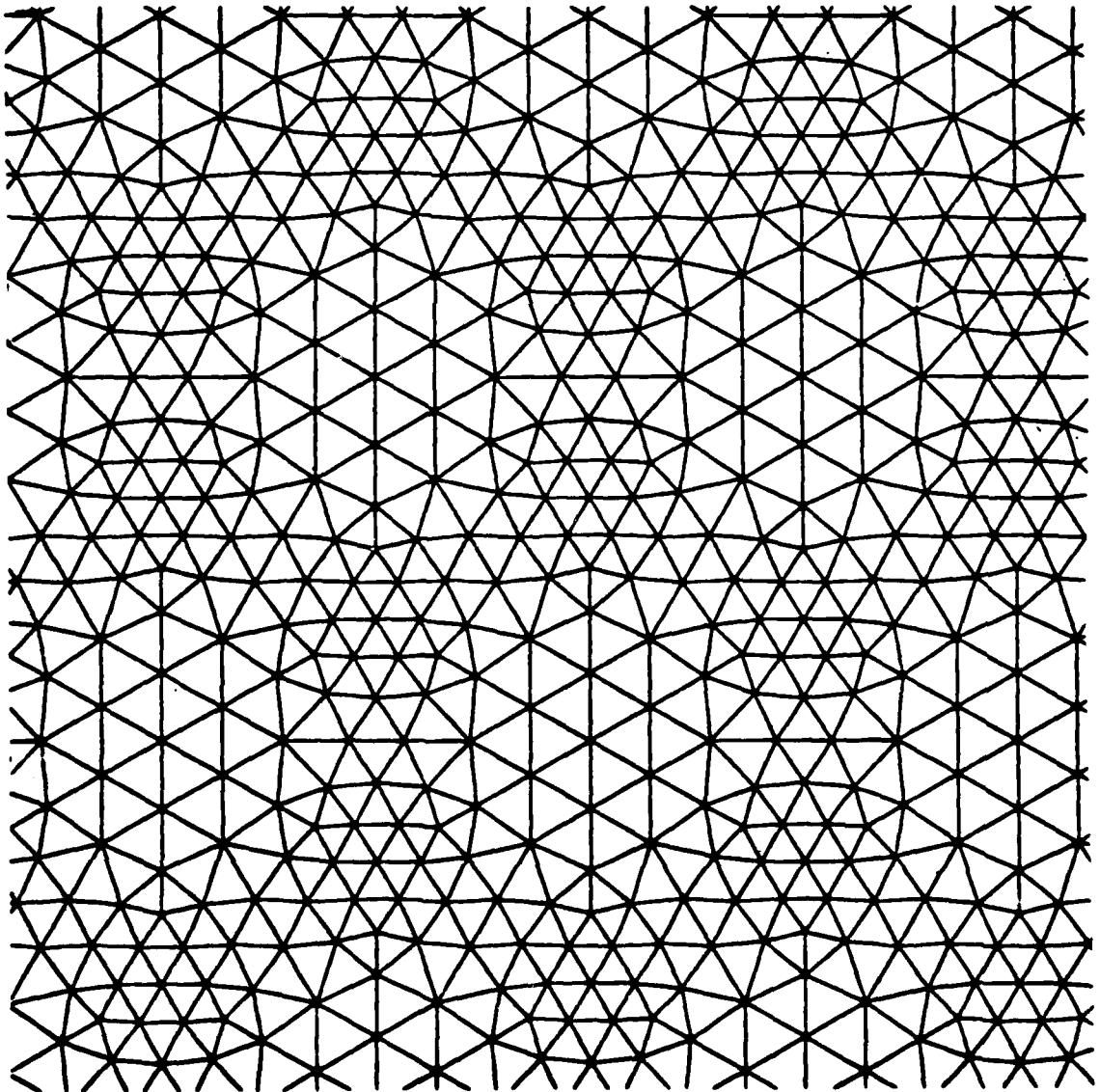
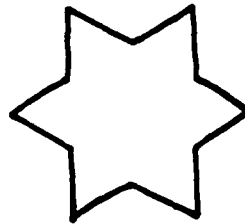
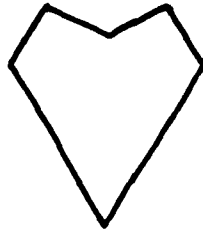


TASK 9 -- Altair Designs (F.C.)

Locate these shapes in the numbered designs and outline them in pencil.

DESIGN #2

(14 Items)



# DISTRIBUTION LIST

## NAVY

- |   |   |
|---|---|
| <p>4 Dr. Jack Adams<br/>Office of Naval Research Branch<br/>223 Old Marylebone Road<br/>London, NW, 15th England</p> <p>1 Dr. Jack R. Borsting<br/>Provost &amp; Academic Dean<br/>U. S. Naval Postgraduate School<br/>Monterey, CA 93940</p> <p>1 Dr. John F. Brock<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Dr. Maurice Callahan<br/>NODAC Code 2<br/>Department of the Navy<br/>Bldg. 2, Washington Navy Yard<br/>Washington, D. C. 20374</p> <p>1 Department of the Navy<br/>CHNAVMAT (NMAT 034D)<br/>Washington, D. C. 20350</p> <p>1 Chief of Naval Education and<br/>Training Support - (01A)<br/>Pensacola, FL 32509</p> <p>1 Capt. H. J. Connery<br/>Navy Medical R&amp;D Command<br/>NNMC<br/>Bethesda, MD 20014</p> <p>1 Dr. Charles E. Davis<br/>ONR Branch Office<br/>536 S. Clark Street<br/>Chicago, IL 60605</p> <p>4 Dr. Marshall J. Farr, Director<br/>Personnel &amp; Training Research<br/>Programs<br/>Office of Naval Research<br/>Code 458<br/>Arlington, VA 22217</p> | <p>1 Dr. Pat Federico<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 CDR John Ferguson, MSC, USN<br/>Naval Medical R&amp;D Command Code 44<br/>National Naval Medical Center<br/>Bethesda, MD 20014</p> <p>1 Dr. John Ford<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Dr. Eugene E. Gloye<br/>ONR Branch Office<br/>1030 East Green Street<br/>Pasadena, CA 91101</p> <p>1 Capt. D. M. Gragg, MC, USN<br/>Head, Section on Medical Education<br/>Uniformed Services Univ. of the<br/>Health Sciences<br/>6917 Arlington Road<br/>Bethesda, MD 20014</p> <p>1 Mr. George N. Graine<br/>Naval Sea Systems Command<br/>Sea 047C112<br/>Washington, D. C. 20362</p> <p>1 Dr. Norman J. Kerr<br/>Chief of Naval Technical Training<br/>Naval Air Station Memphis (75)<br/>Millington, TN 38054</p> <p>1 Dr. Leonard Kroeker<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Chairman, Leadership &amp; Law Dept.<br/>Div. of Professional Development<br/>U. S. Naval Academy<br/>Annapolis, MD 21402</p> |
|---|---|

- |  |   |
|--|---|
| <p>1 Dr. James Lester<br/>ONR Branch Office<br/>495 Summer Street<br/>Boston, MA 02210</p> <p>1 Dr. William L. Maloy<br/>Principal Civilian Advisor for<br/>Education and Training<br/>Naval Training Command, Code 00A<br/>Pensacola, FL 32508</p> <p>1 Dr. James McBride<br/>Code 301<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>2 Dr. James McGrath<br/>Navy Personnel R&amp;D Center<br/>Code 306<br/>San Diego, CA 92152</p> <p>1 Dr. William Montague<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Dr. Robert Morrison<br/>Code 301<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Commanding Officer<br/>Naval Health Research<br/>Center<br/>Attn: Library<br/>San Diego, CA 92152</p> <p>1 CDR Paul Nelson<br/>Naval Medical R&amp;D Command<br/>Code 44<br/>National Naval Medical Center<br/>Bethesda, MD 20014</p> <p>1 Library<br/>Navy Personnel R&amp;D Command<br/>San Diego, CA 92152</p> <p>6 Commanding Officer<br/>Naval Research Laboratory<br/>Code 2627<br/>Washington, D. C. 20390</p> | <p>1 Office of Civilian Personnel<br/>Code 26<br/>Department of the Navy<br/>Washington, D. C. 20390</p> <p>1 John Olsen<br/>Chief of Naval Education &amp;<br/>Training Support<br/>Pensacola, FL 32509</p> <p>1 Office of Naval Research<br/>Code 200<br/>Arlington, VA 22217</p> <p>1 Scientific Director<br/>Office of Naval Research<br/>Scientific Liaison Group/Tokyo<br/>American Embassy<br/>APO San Francisco, CA 96503</p> <p>1 Scientific Advisor to the Chief<br/>of Naval Personnel<br/>Naval Bureau of Personnel (PERS or)<br/>Rm. 4410, Arlington Annex<br/>Washington, D. C. 20370</p> <p>1 Dr. Richard A. Pollak<br/>Academic Computing Center<br/>U. S. Naval Academy<br/>Annapolis, MD 21402</p> <p>1 Dr. Worth Scanland<br/>Chief of Naval Education and Training<br/>Code N-5<br/>NAS, Pensacola, FL 32508</p> <p>1 A. A. Sjöholm<br/>Technical Support<br/>Code 201<br/>Navy Personnel R&amp;D Center<br/>San Diego, CA 92152</p> <p>1 Dr. Alfred F. Smode<br/>Training Analysis &amp; Evaluation Group<br/>(TAEG)<br/>Department of the Navy<br/>Orlando, FL 32813</p> <p>1 Commanding Officer<br/>U. S. Naval Amphibious School<br/>Coronado, CA 92155</p> |
|--|---|

1 CDR Charles J. Theisen,  
JR. MSC, USN  
Head Human Factors Engineering  
Division  
Naval Air Development Center  
Warminster, PA 18974

1 W. Gary Thomson  
Naval Ocean Systems Center  
Code 7132  
San Diego, CA 92152

1 Dr. Martin F. Wiskoff  
Navy Personnel R&D Center  
San Diego, CA 92152

#### ARMY

1 ARI Field Unit-Leavenworth  
P. O. Box 3122  
Ft. Leavenworth, KS 66027

1 Commander  
U. S. Army ADMINCEN  
Attn: ATZI-TD  
Ft. Benjamin Harrison, IN 46218

1 HQ. USAREUE & 7th Army  
ODCSOPS  
USAREUE Director of GED  
APO New York 09403

1 Dr. James Baker  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1 Dr. Ralph Canter  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1 Dr. Ralph Dusek  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1 Dr. Frank J. Harris  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1 Dr. Milton S. Katz  
Individual Training & Skill  
Evaluation Technical Area  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

1 Dr. J. E. Uhlaner  
Chief Psychologist, U. S. Army  
Army Research Institute  
6933 Hector Road  
McLean, VA 22101

1 Dr. Joseph Ward  
U. S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, VA 22333

#### AIR FORCE

1 Air Force Human Resources Lab  
AFHRL/PED  
Brooks AFB, TX 78235

1 Air University Library  
AUL/LSE 76/443  
Maxwell AFB, AL 36112

1 Dr. G. A. Eckstrand  
AFHRL/AS  
Wright-Patterson AFB, OH 45433

1 Dr. Alfred R. Fregly  
AFOSR/NL, Bldg. 410  
Bolling AFB, D. C. 20332

1 CDR Mercer  
CNET Liaison Officer  
AFHRL/Flying Training Division  
Williams AFB, AZ 85224

1 Dr. Ross L. Morgan  
AFHRL/ASR  
Wright-Patterson AFB  
Ohio 45433

1 Personnel Analysis Division  
HQ USAF/DPXXA  
Washington, D. C. 20330

1 Research Branch  
AFMPC/DPMYP  
Randolph AFB, TX 78148

1 Dr. Marty Rockway  
AFHRL/TT  
Lowry AFB  
Colorado 80230

1 Major Wayne S. Sellman  
Chief, Personnel Testing  
AFMPC/DPMYPT  
Randolph AFB, TX 78148

1 Brian K. Waters, Maj., USAF  
Chief, Instructional Tech. Branch  
AFHRL  
Lowry AFB, CO 80230

#### MARINES

1 Director, Office of Manpower  
Utilization  
HQ, Marine Corps (MPU)  
BCB, Bldg. 2009  
Quantico, VA 22134

1 Dr. A. L. Slafkosky  
Scientific Advisor  
Code RD-1  
HQ, U. S. Marine Corps  
Washington, D. C. 20380

#### COAST GUARD

1 Mr. Joseph J. Cowan  
Chief Psychological Research  
G-P-1/62  
U. S. Coast Guard HQ  
Washington, D. C. 20590

#### OTHER DOD

12 Defense Documentation Center  
Cameron Station, Bldg. 5  
Alexandria, VA 22314  
Attn: TC

1 Military Assistance for Human  
Resources  
Office of the Director of  
Defense Research & Engineering  
Room 3D129, the Pentagon  
Washington, D. C. 20301

1 Dr. Harold F. O'Neil, Jr.  
Advanced Research Projects Agency  
Cybernetics Technology, Rm. 623  
1400 Wilson Blvd.  
Arlington, VA 22209

1 Director, Research & Data  
OSD/MRA&L Room 3B919  
The Pentagon  
Washington, D. C. 20301

1 Mr. Fredrick W. Suffa  
MPP (A&R) 2B269  
The Pentagon  
Washington, D. C. 20301

1 Dr. Robert Young  
Advanced Research Projects Agency  
1400 Wilson Blvd.  
Arlington, VA 22209

## CIVILIAN GOVERNMENT

- |   |  |
|---|--|
| 1 Dr. Lorraine D. Eyde<br>Personnel R&D Center<br>U. S. Civil Service Commission<br>1900 E Street, N. W.<br>Washington, D. C. 20415         | 1 Robert W. Stump<br>Education & Work Group<br>National Institute of Education<br>1200 19th Street, N. W.<br>Washington, D. C. 20208 |
| 1 Dr. William Gorham, Director<br>Personnel R&D Center<br>U. S. Civil Service Commission<br>1900 E Street, N. W.<br>Washington, D. C. 20415 | 1 Dr. Vern W. Urry<br>Personnel R&D Center<br>U. S. Civil Service Commission<br>1900 E Street, N. W.<br>Washington, D. C. 20415      |
| 1 Dr. Andrew R. Molnar<br>Science Education Dev.<br>and Research<br>National Science Foundation<br>Washington, D. C. 20550                  | 1 Dr. Joseph L. Young, Director<br>Memory & Cognitive Processes<br>National Science Foundation<br>Washington, D. C. 20550            |
| 1 Dr. Thomas G. Sticht<br>Basic Skills Program<br>National Institute of Education<br>1200 19th Street, N. W.<br>Washington, D. C. 20208     |  |

## NON-GOVERNMENT

- |   |  |
|---|--|
| 1 Professor Earl A. Alluisi<br>Department of Psychology<br>Code 287<br>Old Dominion University<br>Norfolk, VA 23508                     | 1 Dr. Nicholas A. Bond<br>Department of Psychology<br>Sacramento State College<br>600 Jay Street<br>Sacramento, CA 95819       |
| 1 Dr. John R. Anderson<br>Department of Psychology<br>Yale University<br>New Haven, CT 06520  | 1 Dr. John Seeley Brown<br>Bolt Beranek & Newman, Inc.<br>50 Moulton Street<br>Cambridge, MA 02138                             |
| 1 Dr. Michael Atwood<br>Science Applications Institute<br>40 Denver Tech. Center West<br>7935 E. Prentice Avenue<br>Englewood, CO 80110 | 1 Dr. John Carroll<br>Psychometric Laboratory<br>University of North Carolina<br>Davie Hall 013A<br>Chapel Hill, NC 27514      |
| 1 Mr. Samuel Ball<br>Educational Testing Service<br>Princeton, NJ 08540   | 1 Dr. Kenneth E. Clark<br>College of Arts & Sciences<br>University of Rochester<br>River Campus Station<br>Rochester, NY 14627 |
| 1 Dr. Gerald V. Barrett<br>Department of Psychology<br>University of Akron<br>Akron, OH 44325   |  |



- 1 Dr. Norman Cliff  
Department of Psychology  
University of Southern  
California  
University Park  
Los Angeles, CA 90007
- 1 Dr. Allan M. Collins  
Bolt Beranek & Newman, Inc.  
50 Moulton Street  
Cambridge, MA 02138
- 1 Dr. John J. Collins  
Essex Corporation  
201 North Fairfax Street  
Alexandria, VA 22314
- 1 Dr. Meredith Crawford  
5605 Montgomery Street  
Chevy Chase, MD 20015
- 1 Dr. Donald Dansereau  
Department of Psychology  
Texas Christian University  
Fort Worth, TX 76129
- 1 Dr. Rene V. Dawis  
Department of Psychology  
University of Minnesota  
75 E. River Road  
Minneapolis, MN 55455
- 1 Dr. Ruth Day  
Center for Advanced Study  
in Behavioral Sciences  
202 Junipero Serra Blvd.  
Stanford, CA 94305
- 1 Dr. Marvin D. Dunnette  
N492 Elliott Hall  
Department of Psychology  
University of Minnesota  
Minneapolis, MN 55455
- 1 ERIC Facility-Acquisitions  
4833 Rugby Avenue  
Bethesda, MD 20014
- 1 Major I. N. Evonic  
Canadian Forces Pers. Applied  
Research  
1107 Avenue Road  
Toronto, Ontario, Canada
- 1 Dr. Richard L. Ferguson  
The American College Testing Program  
P. O. Box 168  
Iowa City, IA 52240
- 1 Dr. Victor Fields  
Department of Psychology  
Montgomery College  
Rockville, MD 20850
- 1 Dr. Edwin A. Fleishman  
Advanced Research Resources Organ.  
4330 East-West Highway  
Washington, D. C. 20014
- 1 Dr. John R. Frederiksen  
Bolt Beranek & Newman  
50 Moulton Street  
Cambridge, MA 02138
- 1 Dr. Robert Glaser LRDC  
University of Pittsburgh  
3939 O'Hara Street  
Pittsburgh, PA 15213
- 1 Dr. James G. Greeno LRDC  
University of Pittsburgh  
3939 O'Hara Street  
Pittsburgh, PA 15213
- 1 Dr. Richard S. Hatch  
Decision Systems Association, Inc.  
350 Fortune Terrace  
Rockville, MD 20854
- 1 Dr. Barbara Hayes-Roth  
The Rand Corporation  
1700 Main Street  
Santa Monica, CA 90406
- 1 HumRRO Columbus Office  
Suite 23  
2601 Cross Country Drive  
Columbus, GA 31906
- 1 Library  
HumRRO/Western Division  
27857 Berwick Drive  
Carmel, CA 93921

- 1 Dr. Earl Hunt  
Department of Psychology  
University of Washington  
Seattle, WA 98105
- 1 Dr. Lawrence B. Johnson  
Lawrence Johnson & Assoc., Inc.  
Suite 502  
2001 S Street, N. W.  
Washington, D. C. 20009
- 1 Dr. Arnold F. Kanarick  
Honeywell, Inc.  
2600 Ridgeway Pkwy  
Minneapolis, MN 55413
- 1 Dr. Roger A. Kaufman  
203 Dodd Hall  
Florida State University  
Tallahassee, FL 32306
- 1 Dr. Steven W. Keele  
Department of Psychology  
University of Oregon  
Eugene, OR 97403
- 1 Dr. Ezra S. Krendel  
Wharton School, DH/DC  
University of Pennsylvania  
Philadelphia, PA 19174
- 1 LCOL C. R. J. Lafleur  
Personnel Applied Research  
National Defense HQs.  
101 Colonel by Drive  
Ottawa, Canada K1A 0K2
- 1 Dr. Frederick M. Lord  
Educational Testing Service  
Princeton, NJ 08540
- 1 Dr. Robert R. Mackie  
Human Factors Research, Inc.  
6780 Cortona Drive  
Santa Barbara Research Park  
Goleta, CA 93017
- 1 Dr. Richard B. Millward  
Department of Psychology  
Hunter Laboratory  
Brown University  
Providence, RI 02912
- 1 Dr. Donald A. Norman  
Department of Psychology C-009  
University of California,  
San Diego  
La Jolla, CA 92093
- 1 Dr. Melvin R. Novick  
Iowa Testing Programs  
University of Iowa  
Iowa City, IA 52242
- 1 Mr. A. J. Pesch, President  
Eclectech Associates, Inc.  
P. O. Box 178  
N. Stonington, CT 06359
- 1 Mr. Luigi Petrullo  
2431 N. Edgewood Street  
Arlington, VA 22207
- 1 Dr. Peter Polson  
Department of Psychology  
University of Colorado  
Boulder, CO 80302
- 1 Dr. Frank Pratzner  
Center for Vocational Education  
Ohio State University  
1960 Kenny Road  
Columbus, OH 43210
- 1 Dr. Diane M. Ramsey-Klee  
R-K Research & System Design  
3947 Ridgemont Drive  
Malibu, CA 90265
- 1 Min. Rét. M. Rauch  
P II 4  
Bundesministerium Der Verteidigung  
Postfach 161  
53 Bonn 1, Germany
- 1 Dr. Mark D. Reckase  
Educational Psychology Department  
University of Missouri-Columbia  
12 Hill Hall  
Columbia, MO 65201
- 1 Dr. Joseph W. Rigney  
University of Southern California  
Behavioral Technology Labs  
3717 South Hope Street  
Los Angeles, CA 90007

- 1 Dr. Andrew M. Rose  
American Institutes for Research  
1055 Thomas Jefferson Street, N. W.  
Washington, D. C. 20007
- 1 Dr. Leonard L. Rosenbaum,  
Chairman  
Department of Psychology  
Montgomery College  
Rockville, MD 20850
- 1 Professor Fumiko Samejima  
Department of Psychology  
University of Tennessee  
Knoxville, TN 37916
- 1 Dr. Walter Schneider  
Department of Psychology  
University of Illinois  
Champaign, IL 61820
- 1 Dr. Lyle Schoenfeldt  
School of Management  
Rensselaer Polytechnic  
Institute  
Troy, NY 12181
- 1 Dr. Robert J. Seidel  
Instructional Technology  
Group  
HumRRO  
300 North Washington Street  
Alexandria, VA 22314
- 1 Dr. Richard Snow  
School of Education  
Stanford University  
Stanford, CA 94305
- 1 Dr. Robert Sternberg  
Department of Psychology  
Yale University  
Box 11A, Yale Station  
New Haven, CT 06520
- 1 Dr. Albert Stevens  
Bolt Beranek & Newman, Inc.  
50 Moulton Street  
Cambridge, MA 02138
- 1 Dr. Patrick Suppes  
Department of Psychology  
Stanford University  
Stanford, CA 94305
- 1 Dr. Kikumi Tatsuoka  
Computer Based Education Research  
Laboratory  
252 Engineering Research Laboratory  
University of Illinois  
Urbana, IL 61801
- 1 Dr. Perry Thorndyke  
The Rand Corporation  
1700 Main Street  
Santa Monica, CA 90406
- 1 Dr. Benton J. Underwood  
Department of Psychology  
Northwestern University  
Evanston, IL 60201
- 1 Dr. Robert Vineberg  
HumRRO/Western Division  
27857 Berwick Drive  
Carmel, CA 93921
- 1 Dr. Thomas Wallsten  
Psychometric Laboratory  
Davie Hall 013A  
University of North Carolina  
Chapel Hill, NC 27514
- 1 Dr. Claire E. Weinstein  
Educational Psychology Department  
University of Texas at Austin  
Austin, TX 78712
- 1 Dr. David J. Weiss  
N660 Elliott Hall  
University of Minnesota  
75 E. River Road  
Minneapolis, MN 55455
- 1 Dr. Keith Wescourt  
Department of Psychology  
Stanford University  
Stanford, CA 94305
- 1 Dr. Susan E. Whitely  
Psychology Department  
University of Kansas  
Lawrence, KS 66044